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December 5, 2016

VIA ELECTRONIC FILING

Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street S.W.
Washington D.C. 20554

Re: Oral *Ex Parte* Notice
GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95;
RM-11664 and 11773; and WT Docket No. 10-112

Dear Ms. Dortch:

On December 1, 2016, representatives of The Boeing Company ("Boeing") met with staff of the Federal Communications Commission ("Commission") to discuss the above-referenced proceedings and Boeing's further technical analysis regarding spectrum sharing between the Upper Microwave Flexible Use Service ("UMFUS") and next-generation broadband satellite communications systems in the V-band. The discussion tracked closely with the attached technical presentation and with Boeing's comments, reply comments, and its November 21, 2016 *ex parte* letter that were filed in response to the Commission's Further Notice of Proposed Rulemaking in the above captioned proceeding and in response to certain of the comments and reply comments that were filed by other parties in the proceeding. A list of attendees is attached.

Thank you for your attention to this matter. Please contact the undersigned if you have any questions.

Sincerely,

Bruce A. Olcott
Counsel to The Boeing Company

Attachments

December 1, 2016 Ex Parte Meeting Attendees

Wireless Telecommunications Bureau

- John Schauble
- Catherine Schroeder
- Blaise Scinto
- Charles Oliver
- Nancy Zaczek
- Tim Hilfiger (by phone)
- Stephen Buenzow (by phone)

Office of Engineering and Technology

- Michael Ha
- Ed Mantiply
- Bahman Badipour
- Barbara Pavon
- Antonio Lavarello
- Rylan Knight

International Bureau

- Jose Albuquerque
- Chip Fleming

Boeing Participants

- Bruce Chesley
- Robert Vaughan
- Kim Kolb
- Ying Feria
- Bruce Olcott
- Alexander Epshteyn (by phone)

Boeing Discussion of Spectrum Frontiers Reply Comments

December 1, 2016

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TOPICS

- ePFD Correctly Models NGSO Interference into UMFUS
- Corrections to Straight Path Reply Comments
- Multiple Beam UMFUS Handheld Devices (T-Mobile)
- Assessing the Worst-Case NGSO FSS Impacts to UMFUS
- Corrections to Samsung Reply Comments
- Path Forward: Downlink V-Band Sharing
    - 37/39 GHz PFD and ePFD regulations

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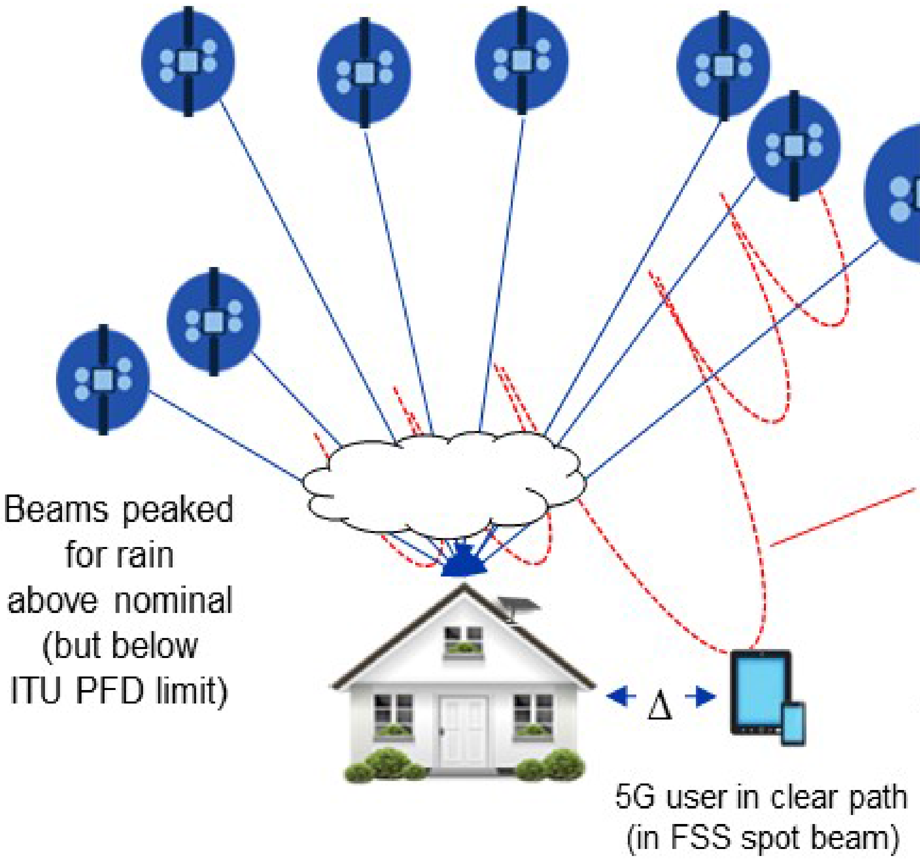
Equivalent PFD ("ePFD") Analyses are Appropriate for Calculating FSS to UMFUS Interference



- Victim 5G receiver antenna pattern reduces total interference from different satellite paths
- "Equivalent PFD" is less than simple aggregate combined

$$ePFD = 10log_{10}\left(\sum_{k=1}^{Nsats} 10^{\frac{(G_r^k(\theta_k,\phi_k)+PFD_k)}{10}}\right) - (G_{r-pk})$$

N_{sats} = Number of total NGSO satellites radiating beams at the particular ground point
PFD_k = incident PFD of the k^{th} NGSO satellite at the ground point in dBW/m2/MHz
$G_r^k(\theta_k, \phi_k)$= Gain of the 5G victim receiver antenna in the direction toward the kth NGSO satellite, in dBi
G_{r-pk} = Peak gain of the 5G victim receiver (usually G_r (0,0) at boresight), in dBi

$$INR_{dB} = [ePFD + G_{r\text{-}pk} - 10\log_{10}(4\pi/\lambda^2) - k - T_r]$$

$$(I/N)_{deg} = 10\log_{10}(10^{(INR/10)}+1)$$

λ = wavelength in m; $\lambda \sim= (0.3/F_c)$ where F_c is in GHz
G_r = Isotropic gain of the 5G receiver in the direction of the arriving PFD signal, in dBi
K = Boltzmann's constant, -228.6 dB W/K-Hz
T_r = 5G receiver noise temperature in dB/K, calculated as $10\log_{10}(T_b+290*[10^{(NF/10)}-1])$ where T_b= background temperature (usually 290K for terrestrial background and/or rain) and NF = noise figure of the 5G receiver in dB

- **ePFD methodology used by FCC for Ku-band NGSO rules and correctly models FSS/UMFUS sharing**
- **Worst-case conditions – rain fade to satellite receivers and clear sky path to UMFUS receivers**

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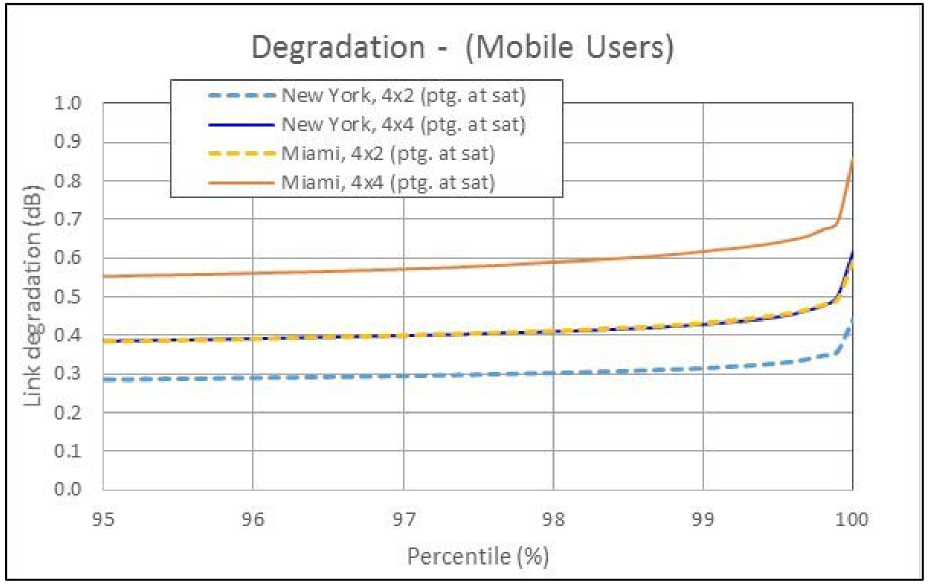
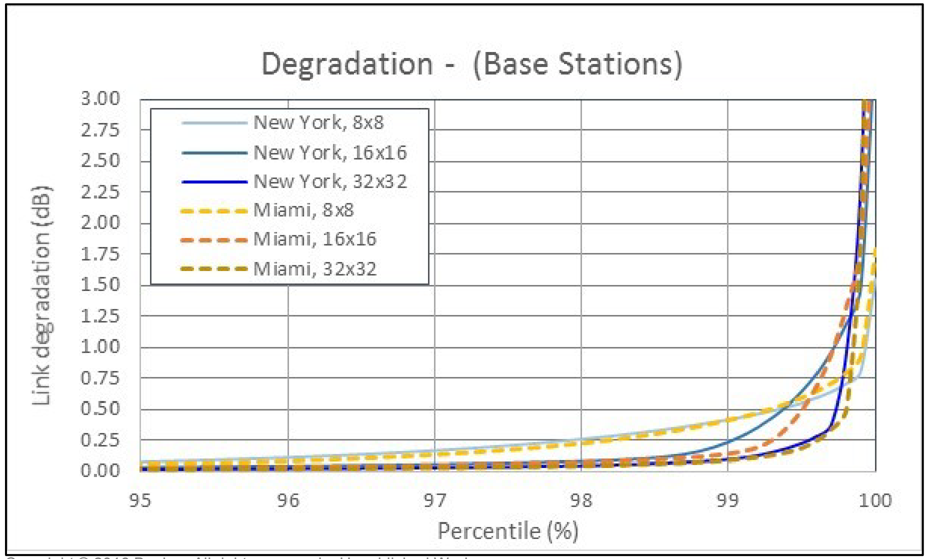
NGSO Operations in Worst-Case Rain Conditions has Negligible Impact on UMFUS





Scenario	5G receiver	Location	ePFD (dBW/m2/MHz) 99%	ePFD (dBW/m2/MHz) 99.5%	Link degradation (noise increase), dB 99%	Link degradation (noise increase), dB 99.5%
1 – Mobile Users	Handset 4x2	New York	-108.1	-107.9	0.31	0.33
	Handset 4x4		-109.7	-109.5	0.43	0.45
1 – Mobile Users	Handset 4x2	Miami	-106.7	-106.5	0.43	0.45
	Handset 4x4		-108.1	-107.8	0.62	0.64
2a – Transportable CPE	CPE (8X8)	New York	-128.2	-127.5	0.020	0.022
2b – Transportable CPE	CPE (8x8)	Miami	-127.5	-126.7	0.022	0.026
3a - Base Stations (random ptg)	64 elem (8x8)	New York	-116.5	-115.0	0.42	0.55
	256 elem (16x16)		-125.1	-120.4	0.24	0.65
	1024 elem (32x32)		-135.0	-131.2	0.10	0.23
3a - Base Stations (random ptg)	64 elem (8x8)	Miami	-116.4	-115.0	0.42	0.60
	256 elem (16x16)		-127.0	-121.5	0.15	0.50
	1024 elem (32x32)		-135.2	-132.0	0.10	0.19
3b - Base Stations (Urban Micro)	64 elem (8x8)	New York	-129.3	-128.5	0.023	0.027
	256 elem (16x16)		-127.0	-136.0	0.016	0.018
	1024 elem (32x32)		-144.2	-143.2	0.012	0.014
3b - Base Stations (Urban Micro)	64 elem (8x8)	Miami	-129.0	-128.0	0.026	0.031
	256 elem (16x16)		-136.1	-135.5	0.018	0.022
	1024 elem (32x32)		-135.4	-142.6	0.014	0.017

Impact to UMFUS is less than 0.65 dB in all cases with a 99.5% confidence level using improbable worst-case conditions – rain fade to satellite receivers and clear sky to UMFUS

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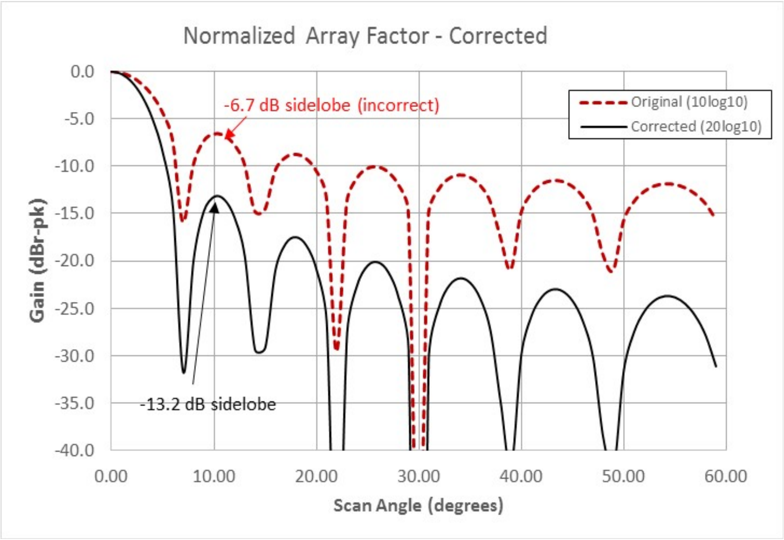
Interference to Noise and Noise Floor "Rise" Analyses Require Correct Modeling of Receive Antenna Pattern



INCORRECT MODEL:

$$A(\theta) = 10\log_{10}\left(\left|\frac{\sin\left(\frac{N\pi}{2}(\cos\theta - \cos\phi)\right)}{\sin\left(\frac{\pi}{2}(\cos\theta - \cos\phi)\right)}\right|\right) + G_{E,max} + A_{E,V}(\theta)$$

CORRECT MODEL:

$$A(\theta) = 10log10(N) + 20log_{10}\left(\left|\frac{sin\left(\frac{N\pi}{2}(\cos(\theta) - \cos(\phi))\right)}{Nsin\left(\frac{\pi}{2}(\cos(\theta) - \cos(\phi))\right)}\right|\right) + G_{E,max} + A_{E,V}(\theta)$$

- **All interference analyses must use receive antenna gain patterns to assess impact on UMFUS**
- **Numerous UMFUS proponents discuss plans to use planar arrays in various configurations**
  - **3GPP reference model is a good example referenced by many commenters**
- **Uniform linear array antenna pattern equation used by Straight Path has an error in response level**
  - **20*log10(| . |) is required for array factor E-field voltage response (versus 10*log10(| . |) used)**
  - **Has a significant impact on expected sidelobe levels predicting levels twice as high as will actually occur**

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Corrected Analyses Show Minimal and Acceptable Degradations for Base Station Operations

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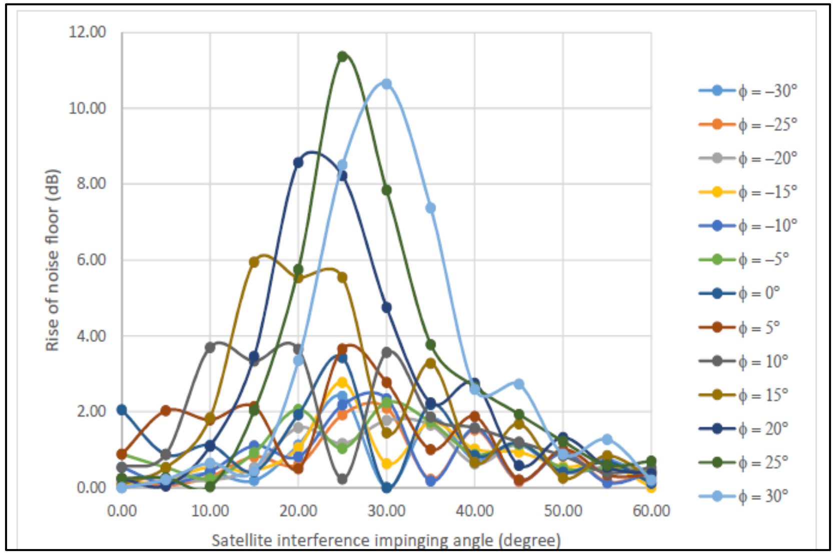
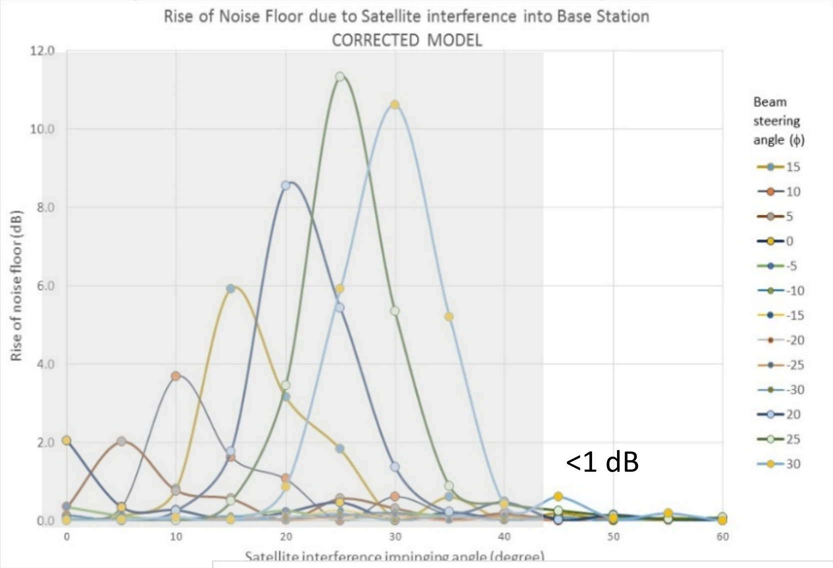
ORIGINAL – BASE STATION CASE



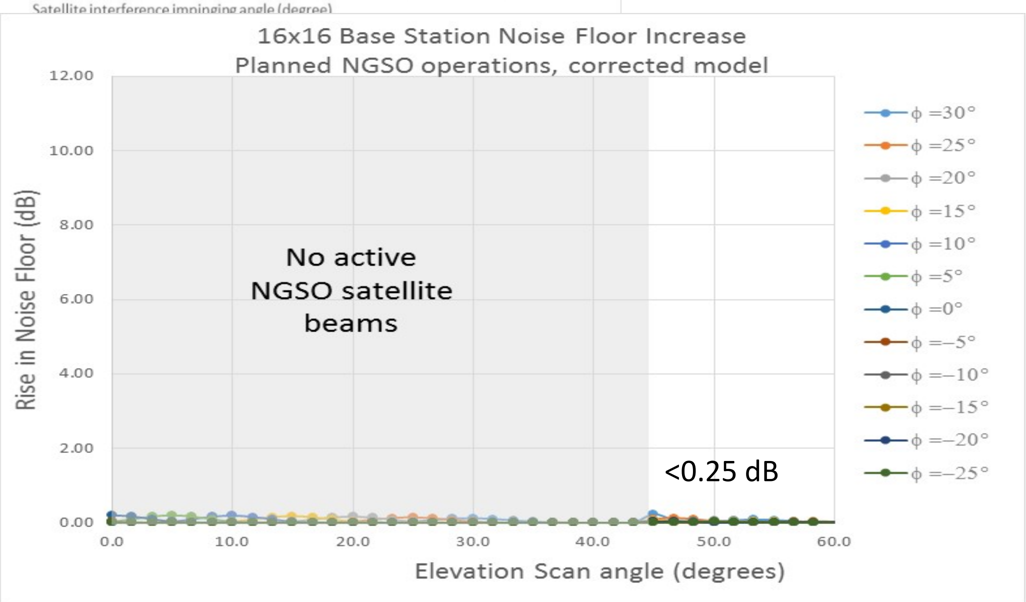
Rise in Noise Floor (Straight Path Figure 10)

CORRECTED ANTENNA MODEL



Corrected analyses show NGSO operations will not significantly impact 5G operations beyond “manageable” levels

With planned NGSO operating approach (satellites above 45 deg. and using power control)



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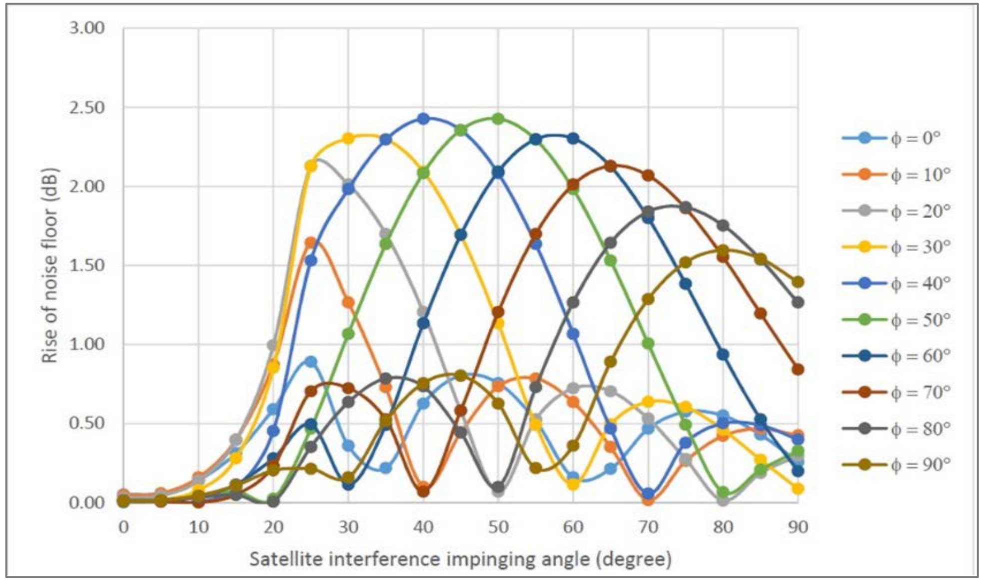
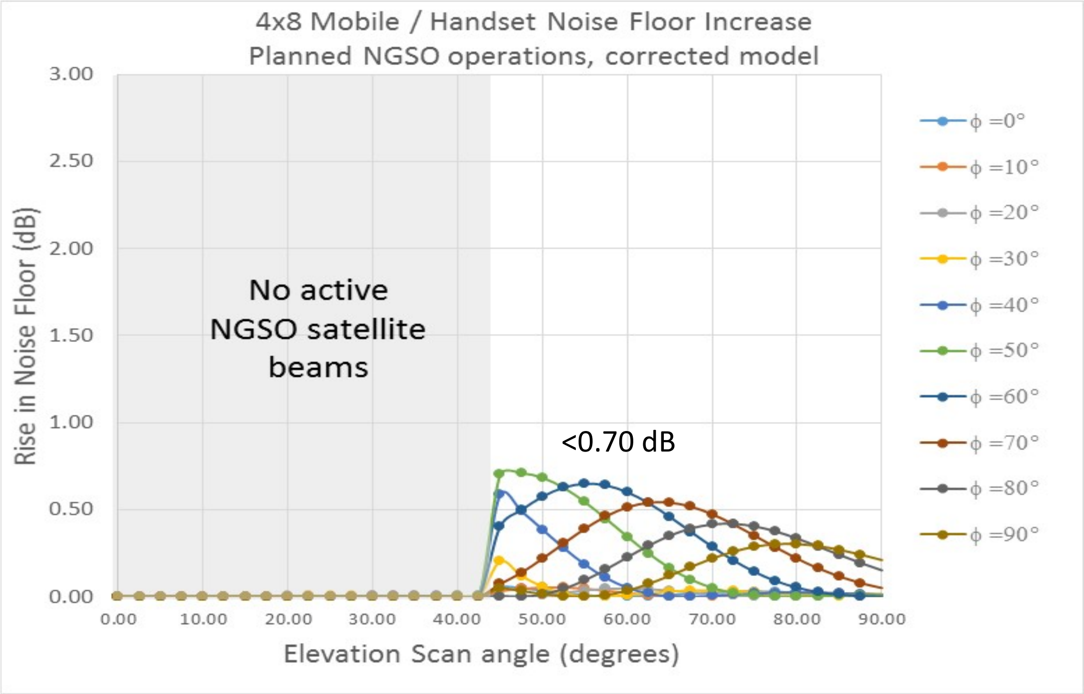
Corrected Analyses Show Minimal and Acceptable Degradations for UMFUS Mobile/Handset Operations

ORIGINAL – MOBILE STATION CASE



Rise in Noise Floor (Straight Path Figure 7)

CORRECTED with NGSO operating approach (satellites above 45 deg. and using power control)



Impacts to UMFUS handsets remain small even when handset pointing upwards or mis-pointing

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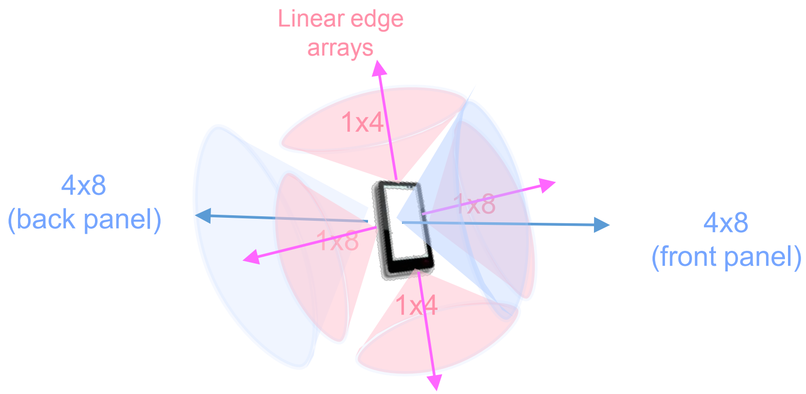
NGSO Downlink Operations into Complex Multi-beam Handsets is Already Incorporated in Boeing's Analyses

- T-Mobile expressed concern that mobile devices may include "multiple antenna arrays at different UE corners and/or sides"
  - Arrays embedded in different faces of a devices are used to provide a ~spherical 4π steradian coverage
  - The appropriate antenna sector is selected and an electronic beam is formed towards a base station signal



- Boeing's handset/mobile device model for UMFUS allows for any orientation and gains of antenna arrays on various device faces
- Worst-case noise floor degradations into each active UMFUS beam are independent – examples are shown in the table
- ePFD approach accounts for all visible satellites into any of the beams, ensuring protection of all UMFUS antenna arrays

Array configuration	Peak Gain (dBi)	99.5% degradation with mispointing
1x4 (top/bottom)	10-11 dBi	0.2-0.25 dB
1x8 (sides)	13-14 dBi	0.35-0.45 dB
4x8 (front/back panels)	19 dBi	0.65 dB

Mobile devices can have multiple beams "searching" for base stations.
When correctly steered, degradations will be well below worst-case 0.65 dB levels.

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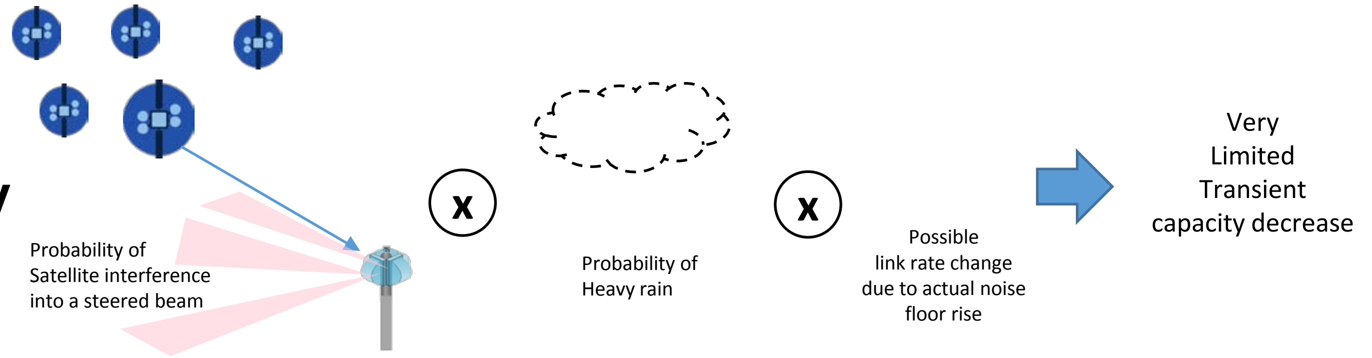
Impacts of NGSO Operations and Noise Floor Degradations are Both Minimal and Transient

- **Straight Path incorrectly claims worst-case noise floor increases will continuously reduce UMFUS capacity and range for every UMFUS base station and user nationwide**
- **Worst-case noise floor increases will occur only a fraction of the time (due to satellite motion) and only then during heavy rain fade events**
- **A corrected presentation of the actual transient degradations and capacity impacts is shown at right**



PARAMETER	UNITS	I/N=-8	I/N=-6	COMMENT
Link degradation due to satellite interference	dB	0.65	1.0	Rise in noise floor, satellite in view in heavy rain fade
Probability of satellite interference (as calculated in heavy rain fade)	%	1.0%	1.0%	99% of the time the degradation is less than above
Probability of rain fade	%	10.0%	10.0%	90% of the time it is NOT raining
Total Probability of degradation event	%	0.10%	0.10%	Total % of time degradation may exist
Nominal spectral efficiency (no interference)	bps/Hz	2.0	2.0	Average - can be lower or higher
Capacity decrease due to degradation	%	7.9%	12.1%	During the transient ONLY, at certain spots with high rain
Total system capacity impact	%	0.0079%	0.0121%	Very small
Percent of design capacity achieved	%	99.992%	99.988%	Very high

- **Highly conservative assumptions are still in place in this assessment (*e.g.*, rain to FSS user, but no rain to any UMFUS users)**

NGSO FSS interference impacts to UMFUS operations are both minimal and transient. High availability and planned capacity (99.9%+) are achieved by UMFUS deployments.

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Other Fixed PFD and I/N Analysis Corrections

- **Samsung includes an Appendix confirming many aspects of PFD and I/N analyses**
- **Recommends -6 dB I/N with 1 dB noise floor degradation used in derivations**
- **Incorrectly uses 28 GHz band (uplink) to derive downlink PFD levels**
- **Resulting downlink PFD recommendations would be about 3 dB <u>higher</u> when corrected**
- **Incorrectly suggest Boeing's recommended ePFD levels (which are 3 dB lower in handset cases) could be a general "3 dB aggregation effect" of the constellation**
  - **ePFD differences from a single satellite PFD depend heavily on the receiver antenna gain pattern**
  - **ePFD levels for higher gain beams are much lower than ePFD levels into a broad low-gain beam**

Samsung Attachment 1 Table (section D) – ORIGINAL and CORRECTED

5G UMFUS Unit Type	MS				TS		
Array Configuration	1x4 or 2x2	1x6 or 2x3	1x8 or 2x4	4x4	4x4	4x8	8x8
Total Elements	4	6	8	16	16	32	64
GRx (dBi)	10	11.8	13	16	16	19.1	22.1
GRx_roffoff (dBr)	0	0	0	0	0	0	0
Absolute Gain (dBi)	10	11.8	13	16	16	19.1	22.1
NF (dB)	7	7	7	7	6	6	6
Frequency (GHz)	~~28~~ 39	~~28~~ 39	~~28~~ 39	~~28~~ 39	~~28~~ 39	~~28~~ 39	~~28~~ 39
Noise Floor in front of mobile receiver antenna (dBW/MHz)	-147.0	-148.8	-150.0	-153.0	-154.0	-157.1	-160.1
PFD limit (dBW/m2/MHz)	~~-102.6~~ -99.7	~~-104.4~~ -101.5	~~-105.6~~ -102.7	~~-108.6~~ -105.7	~~-109.6~~ -106.7	~~-112.7~~ -109.8	~~-115.7~~ -112.8

Corrected levels at or above ITU PFD limit worst-case, mis-pointed mobile/UE (higher than ePFD recommendation)

TS (CPE) fixed device should not be electronically "mis-pointing" at satellite

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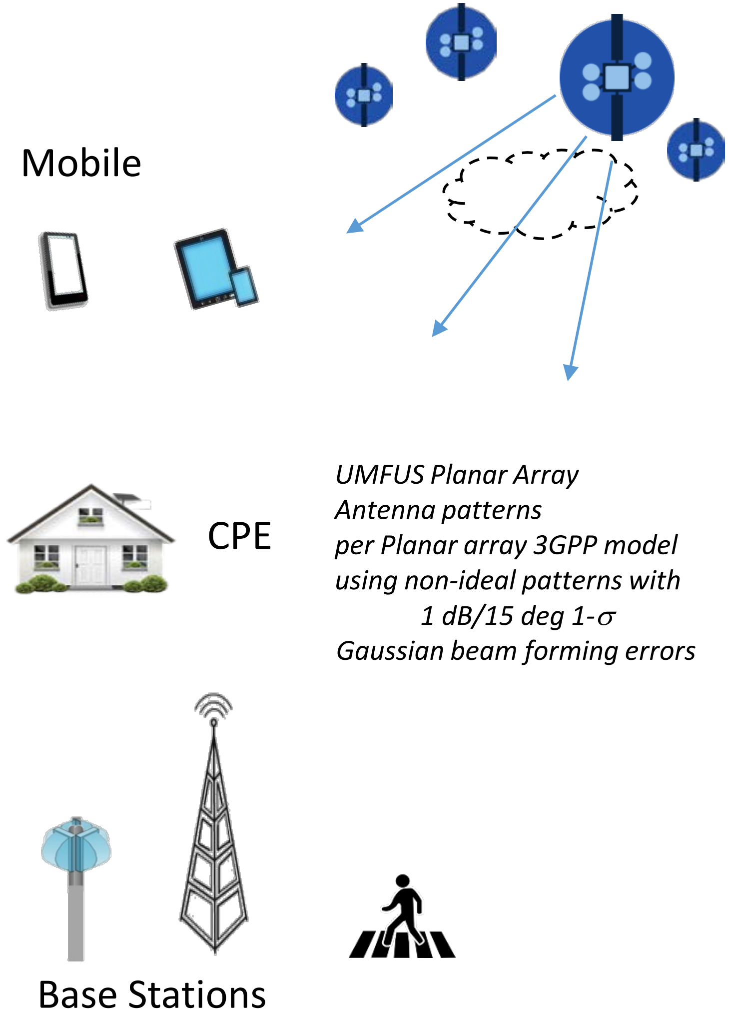
Downlink V-band ePFD Regulations – UMFUS Devices Applicable in all Conditions (rain fade and power control applied)

NGSO Constellation ePFD into UMFUS Devices	37.5-40.0 GHz Equivalent PFD and %-tile	Link Degradation* (NF & noise floor rise)
UMFUS mobile UE 4x4 planar array, G_{pk}=16 dBi 4x8 planar array, G_{pk}=19 dBi Arbitrary device pointing	 -108.0 dBW/m^2/MHz 99.5% -108.0 dBW/m^2/MHz 99.5%	 NF=7 dB, degr. < 0.6 dB NF=7 dB, degr. < 1 dB
UMFUS transportable / CPE 4x8 planar array, G_{pk}=19 dBi 8x8 planar array, G_{pk}=22 dBi Array orientation 0-deg tilt (horizontal) Random electronic steering over +/- 60 deg radial angle (half-cone angle)	 -112.0 dBW/m^2/MHz 99.5% -115.0 dBW/m^2/MHz 99.5%	 NF=7 dB, degr. < 0.6 dB NF=7 dB, degr. < 0.6 dB
UMFUS base station 16x16 planar array, G_{pk}=27 dBi 32x32 planar array, G_{pk}=33 dBi Array orientation 0-deg tilt (horizontal) Random electronic steering over +/- 60 deg radial angle (half-cone angle)	 -122.0 dBW/m^2/MHz 99.5% -128.0 dBW/m^2/MHz 99.5%	 NF=5 dB, degr. < 0.65 dB NF=5 dB, degr. < 0.5 dB

(for information only – noise figure etc. is not part of ePFD regulations)*



NGSO ePFD regulations augmenting 25.208(r) are ready for consideration

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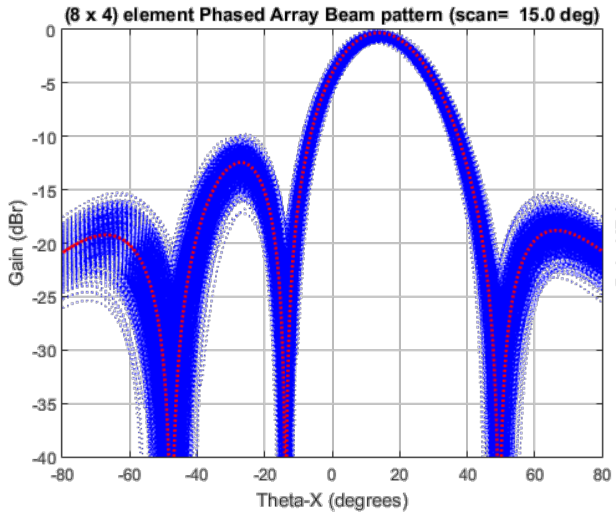
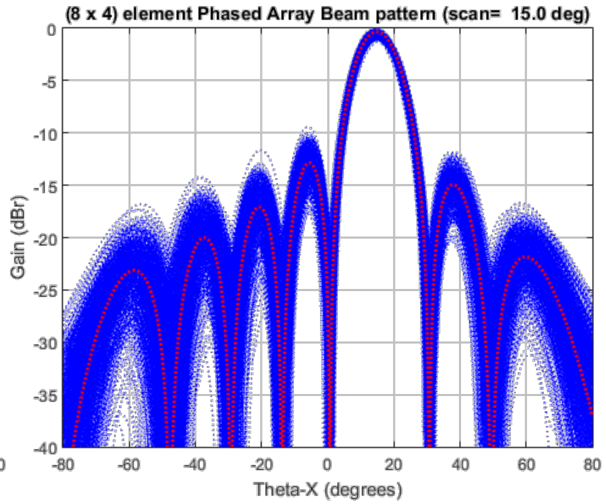
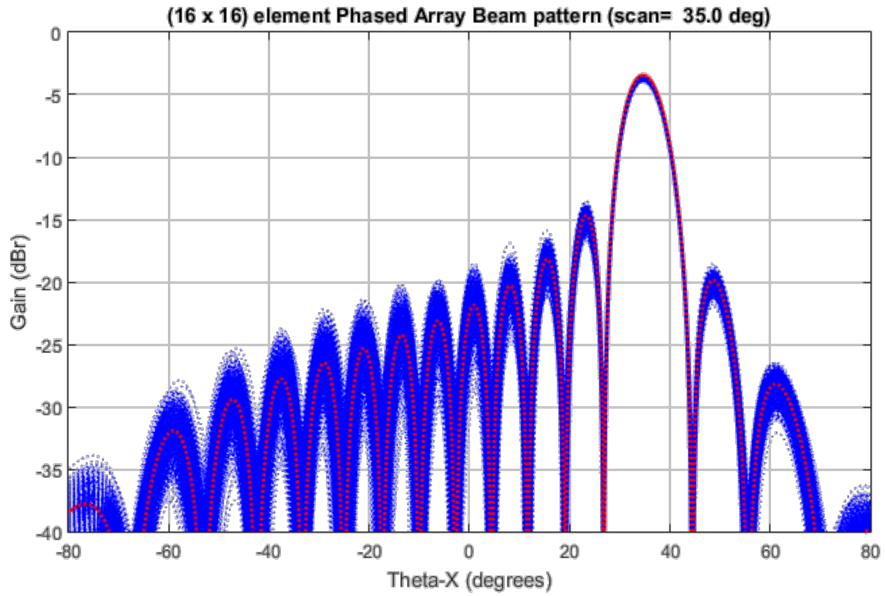
Antenna Pattern Examples with Beamforming Errors

EXAMPLES OF UMFUS ANTENNA PATTERN LEVELS using 3GPP Antenna Model
with 1 dB (1σ) Gaussian random amplitude and 15-deg (1σ) Gaussian random phase errors





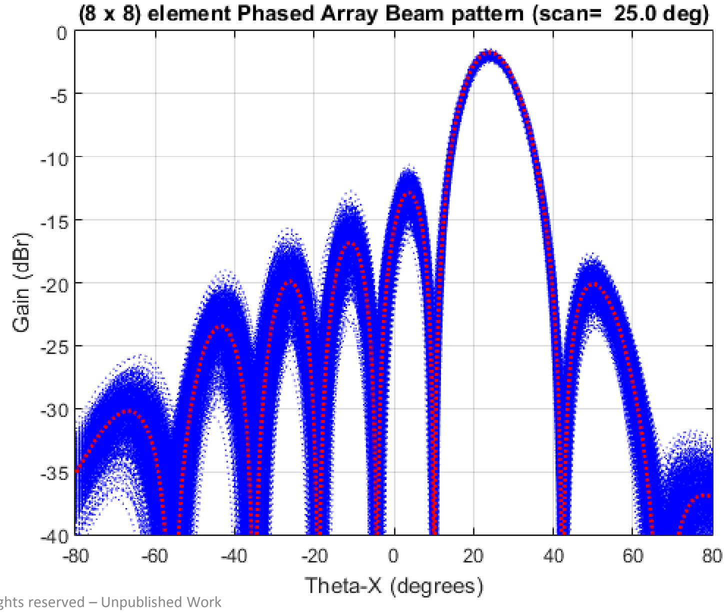
Handset/
Mobile
(4x8)



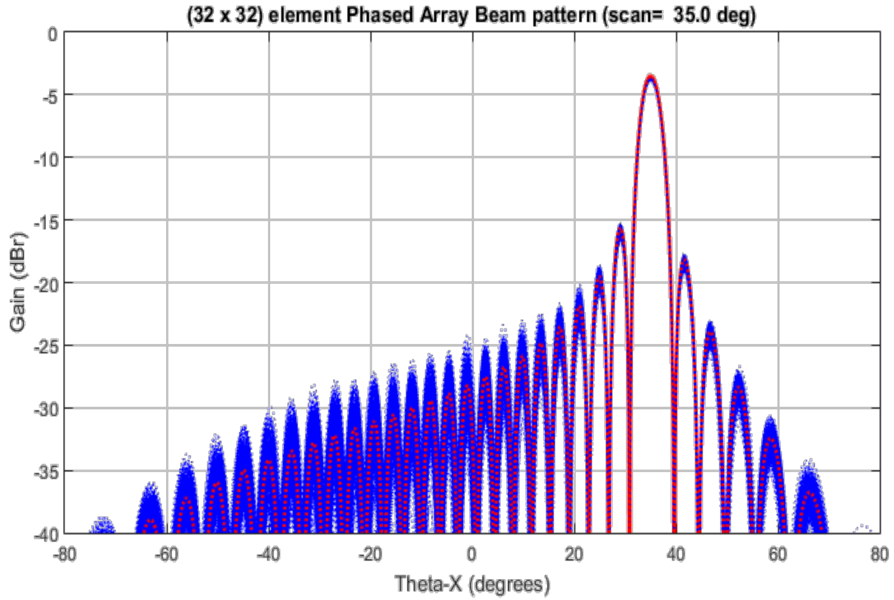
Base
Station
(16x16)

Ideal pattern

With errors



CPE
(8x8)



Base
Station
(32x32)

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